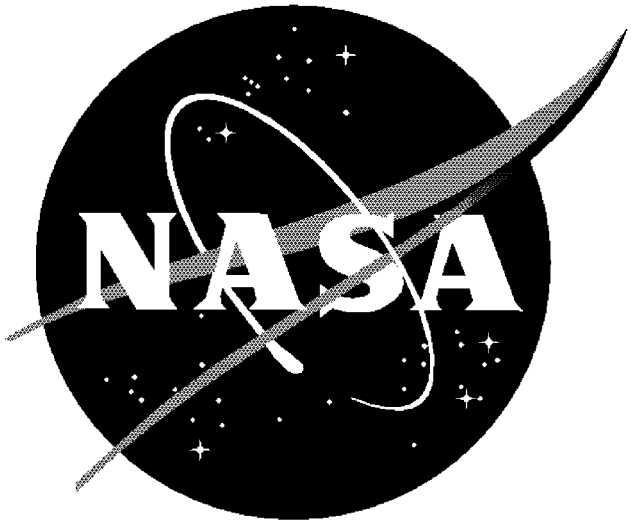
METRIC/INCH-POUND

NASA-STD-5005
MAY 10, 1996

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
DESIGN CRITERIA STANDARD

GROUND SUPPORT EQUIPMENT



FOREWORD

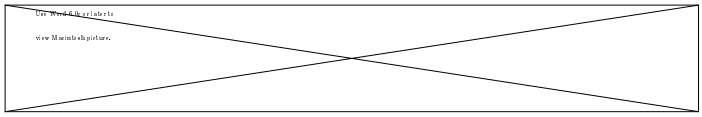
This standard is approved for use by NASA Headquarters and all field installations and is intended to provide a common framework for consistent practices across NASA programs.

This standard was developed to establish uniform engineering practices and methods and to ensure the inclusion of essential criteria in the design of ground support equipment (GSE) used by or for NASA. The standard was prepared by an intercenter committee on GSE and approved by the Engineering Management Council (EMC). This standard is applicable to GSE that supports space vehicle or payload programs or projects. This standard does not apply to facilities.

This standard establishes preferred practices for the design of GSE used by or for the National Aeronautics and Space Administration (NASA) programs and projects. This standard is recommended for the design of nonflight hardware and software used to support the operations of receiving, transportation, handling, assembly, inspection, test, checkout, service, and launch of space vehicles and payloads at NASA launch, landing, or retrieval sites. These criteria and practices may be used for items used at the manufacturing, development, and test sites upstream of the launch, landing, or retrieval sites.

This standard is not self-imposing. It may be cited in contracts and program documents as a technical requirement or as a reference for guidance. Determining the suitability of this standard and its provisions is the responsibility of program/project management and the performing organization. Individual provisions of this standard may be tailored (i.e., modified or deleted) by contract or program specifications to meet specific program/project needs and constraints.

Requests for information, corrections, or additions to this standard should be directed to the Engineering Development Directorate, Mail Code: DE, Kennedy Space Center, Florida 32899, using the form attached to the back of this standard. Requests for additional copies of this standard should be sent to the nearest NASA installation library or documentation repository.



Daniel R. Mulville
Chief Engineer

CONTENTS

CONTENTS

CONTENTS

CONTENTS

PARAGRAPH PAGE

CONTENTS

GROUND SUPPORT EQUIPMENT

1. SCOPE

1.1 Purpose. This standard establishes the general characteristics, performance, design, test, safety, reliability, maintainability, supportability, and quality requirements for ground support systems and equipment intended for use at NASA launch, landing, or retrieval locations. This standard specifies the criteria to provide simple, robust, safe, reliable, maintainable, supportable, and cost-effective ground support equipment (GSE) necessary to support space vehicle and payload launch operations.

1.2 Applicability. This standard recommends preferred engineering practices for NASA programs and projects. It may be cited in contracts and program documents as a technical requirement or as a reference for guidance. Determining the suitability of this standard and its provisions is the responsibility of program/project management and the performing organization. Individual provisions of this standard may be tailored (i.e., modified or deleted) by contract or program specifications to meet specific program/project needs and constraints.

This standard is not intended to be self-imposing. The criteria specified herein shall be the baseline or preferred guidelines for NASA programs, but selection and tailoring to meet specific needs are the responsibility of individual programs. Existing programs and contracts may continue to use existing program or contract-unique GSE design requirements for the life of the program or contract (including follow-on contracts) on existing or new GSE for that program or contract. Retrofit of existing GSE to comply with this standard is at the discretion of the applicable program or project office. When this standard is used in a procurement action, the standard should be reviewed by the program/project office for applicability, and only the sections that apply to the project or program should be included in the procurement documentation. The revision of this standard that was current at the time directions are issued to design, construct, manufacture, or procure the GSE shall be applicable for the useful life of the GSE. Modifications of existing GSE may be done so the modified GSE complies with the revision that is current at the time directions are issued to modify the GSE. This standard does not apply to facilities.

The criteria of this standard may be used for the GSE used at the manufacturing, development, or test sites prior to arrival at the launch, landing, or retrieval sites. This standard is recommended for the design of nonflight hardware and software used to support the operations of transporting, receiving, handling, assembly, test, checkout, service, and launch of space vehicles and payloads at the launch, landing, or retrieval sites. The criteria specified in this standard are recommended for high-risk program and project GSE. GSE for medium- and low-risk programs and projects may use the criteria stated herein at the discretion of the program/project office. Refer to NHB 7120.5 for definition of the high-, medium-, and low-risk programs and projects.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in this standard. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in this standard, whether or not they are listed.

2.2 Government documents

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues in effect on the date of invitation for bids or request for proposals shall apply.

SPECIFICATIONS

GEORGE C. MARSHALL SPACE FLIGHT CENTER (MSFC), NASA

MSFC-PROC-186	-	Potting and Molding Cable Assemblies Using Elastomeric Compounds
MSFC-PROC-380	-	Potting, Encapsulating and Molding, Using Silicone Rubber
MSFC-SPEC-164	-	Cleanliness of Components for use in Oxygen, Fuel and Pneumatic Systems, Specification for
MSFC-SPEC-222	-	Resin Compounds, Electrical and Environmental Insulation, Epoxy
MSFC-SPEC-250	-	Protective Finishes for Space Vehicle Structures and Associated Flight Equipment, General Specification for
MSFC-SPEC-379	-	Compounds, Potting and Encapsulating, Silicone
MSFC-SPEC-515	-	Material, Potting, and Molding, Elastomeric, Urethane
MSFC-SPEC-522	-	Design Criteria for Controlling Stress Corrosion Cracking

JOHN F. KENNEDY SPACE CENTER (KSC), NASA

KSC-C-123	-	Surface Cleanliness of Fluid Systems, Specification for
KSC-E-165	-	Electrical Ground Support Equipment, Fabrication, Specification for
KSC-SPEC-E-0029	-	Compound, Potting and Molding, Elastomeric, Specification for
KSC-SPEC-E-0031	-	Electrical Cables, General Specification for
KSC-SPEC-Z-0008	-	Fabrication and Installation of Flared Tube Assemblies and Installation of Fittings and Fitting Assemblies, Specification for
KSC-SPEC-Z-0009	-	Lubrication, Thread, Corrosion-Resistant Steel and Aluminum Alloy Tube Fittings, Specification for

LYNDON B. JOHNSON SPACE CENTER (JSC), NASA

NSTS-SN-C-0005	-	Contamination Control Requirements, Specification for

MILITARY

MIL-B-7883	-	Brazing of Steels, Copper, Copper Alloys, Nickel, Nickel Alloys, Aluminum and Aluminum Alloys
MIL-C-5015	-	Connectors, Electrical, Circular Threaded, AN Type, General Specification for
MIL-C-22992	-	Connectors, Plugs and Receptacles, Electrical, Waterproof, Quick Disconnect, Heavy Duty Type, General Specification for
MIL-C-26482	-	Connectors, Electrical (Circular, Miniature, Quick Disconnect, Environment Resisting), Receptacles and Plugs, General Specification for

MIL-C-38999	-	Connector, Electrical, Circular, Miniature, High Density Quick Disconnect (Bayonet, Threaded and Breech Coupling), Environment Resistant, Removable Crimp and Hermetic Solder Contacts, General Specification for
MIL-C-39012	-	Connectors, Coaxial, Radio Frequency, General Specification for
MIL-H-6088	-	Heat Treatment of Aluminum Alloys
MIL-H-6875	-	Heat Treatment of Steel, Process for
MIL-H-81200	-	Heat Treatment of Titanium and Titanium Alloys
MIL-I-6870	-	Inspection Program Requirements, Nondestructive for Aircraft and Missile Materials and Parts
MIL-M-8090	-	Mobility, Towed Aerospace Ground Equipment, General Requirements for
MIL-M-8609	-	Motors, Direct-Current, 28 Volt System, Aircraft, General Specification for
MIL-S-16216	-	Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100)
MIL-W-5086	-	Wire, Electric, Polyvinyl Chloride Insulated, Copper or Copper Alloy
MIL-W-16878	-	Wire, Electrical, Insulated, General Specification for
MIL-W-22759	-	Wire, Electrical, Fluoropolymer-Insulated Copper or Copper Alloy

NATIONAL BUREAU OF STANDARDS (NBS)

NBS Handbook 105-1	-	Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NSS/GO-1740.9	-	NASA Safety Standard for Lifting Devices and Equipment

GEORGE C. MARSHALL SPACE FLIGHT CENTER (MSFC), NASA

MSFC-STD-156	-	Riveting, Fabrication and Inspection, Standard for
MSFC-STD-486	-	Threaded Fasteners, Torque Limits, Standard for

JOHN F. KENNEDY SPACE CENTER (KSC), NASA

KSC-STD-C-0001	-	Standard for Protective Coating of Carbon Steel, Stainless Steel, and Aluminum on Launch Structures, Facilities, and Ground Support Equipment
KSC-STD-E-0004	-	Pneumatic and Hydraulic Mechanical Components, Electrical Design, Standard for
KSC-STD-Z-0005	-	Design of Pneumatic Ground-Support Equipment, Standard for
KSC-STD-Z-0006	-	Design of Hypergolic Propellants Ground Support Equipment, Standard for
KSC-STD-Z-0008	-	Design of Ground Life Support Systems and Equipment, Standard for

FEDERAL

FED-STD-595	-	Colors Used in Government Procurement
29 CFR 1910	-	Occupational Safety and Health Administration, Labor (Occupational Safety and Health Standards)
49 CFR 171 to 181	-	Subchapter C, Hazardous Materials Regulations

MILITARY

MIL-STD-171	-	Finishing of Metal and Wood Surfaces
MIL-STD-461	-	Control of Electromagnetic Interference Emissions and Susceptibility, Requirements for
MIL-STD-462	-	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-701	-	List of Standard Semiconductor Devices
MIL-STD-810	-	Environmental Test Methods and Engineering Guidelines
MIL-STD-889	-	Dissimilar Metals
MIL-STD-975	-	NASA Standard Electrical, Electronic and Electromechanical (EEE) Parts List
MIL-STD-1472	-	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MIL-STD-1576	-	Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems

HANDBOOKS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NHB 1620.3	-	NASA Security Handbook
NHB 7120.5	-	Management of Major System Programs and Projects Handbook
NHB 8060.1	-	Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion

JOHN F. KENNEDY SPACE CENTER, NASA

KHB 1700.7	-	Space Shuttle Payload Ground Safety Handbook

MILITARY

MIL-HDBK-5	-	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-149	-	Rubber
MIL-HDBK-454	-	Electronic Equipment, General Guidelines for
MIL-HDBK-700	-	Plastics

TECHNICAL MANUALS AND REPORTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

TM-4511	-	Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, 1993 Revision

JOHN F. KENNEDY SPACE CENTER (KSC), NASA

GP-986	-	KSC Design Criteria for Reusable Space Vehicle Umbilical Systems

MILITARY

TM 5-809-10/NAVFAC P-355/AFM 88-3, Chapter 13	-	Seismic Design for Buildings
EWR 127-1	-	Range Safety Requirements Eastern and Western Range

MANAGEMENT INSTRUCTIONS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

NMI 8010.2	-	Use of the Metric System of Measurement in NASA Programs

(Unless otherwise indicated, copies of the above documents are available from any NASA installation library or documentation repository.)

2.3 Nongovernment publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues in effect on date of invitation for bids or request for proposals shall apply.

ALUMINUM ASSOCIATION (AA)

SAS 30	-	Specifications for Aluminum Structures Construction Manual
SAS 33	-	Engineering Data for Aluminum Structure Construction Manual

(Application for copies should be addressed to the Aluminum Association, 900 19th Street, N.W., Washington, DC 20006.)

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 318	-	Building Code Requirements for Reinforced Concrete

(Application for copies should be addressed to the American Concrete Institute, P.O. Box 19150, Redford Station, Detroit, MI 48219.)

AMERICAN IRON AND STEEL INSTITUTE (AISI)

AISI SG 673, Part I	-	Cold-Formed Steel Design Manual, Specification for the Design of Cold-Formed Steel Structural Members

(Application for copies should be addressed to the American Iron and Steel Institute, 1133 15th Street, N.W., Suite 300, Washington, DC 20005.)

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

M016	-	Manual of Steel Construction - Allowable Stress Design
M015L	-	Manual of Steel Construction - Load and Resistance Factor Design

(Application for copies should be addressed to the American Institute of Steel Construction, Inc., 1 East Wacker Drive, Suite 3100, Chicago, IL 60601-2001.)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI A10.8	-	Construction and Demolition Operations - Scaffolding - Safety Requirements

(Application for copies should be addressed to the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.)

AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR-CONDITIONING ENGINEERS (ASHRAE)

No number	-	ASHRAE Handbooks

[Application for copies should be addressed to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 1791 Tullie Circle, N.E., Atlanta, GA 30329.]

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME A13.1	-	Scheme for the Identification of Piping Systems
ASME B30.1	-	Jacks
ASME B31.3	-	Chemical Plant and Petroleum Refinery Piping
ASME Boiler and Pressure Vessel Code, Section VIII, Divisions I and II	-	Rules for Construction of Pressure Vessels
ASME Boiler and Pressure Vessel Code, Section IX	-	Welding and Brazing Qualifications

(Application for copies should be addressed to the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.)

AMERICAN SOCIETY FOR QUALITY CONTROL (ASQC)

ANSI/ASQC Q9001	-	Quality Systems – Model for Quality Assurance in Design, Development, Production, Installation, and Servicing

(Application for copies should be addressed to the American Society for Quality Control, 611 E. Wisconsin Avenue, Milwaukee, WI 53202-4606.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM A269	-	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A514	-	Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding
ASTM A517	-	Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered
ASTM E380	-	Use of the International System of Units (SI) (the Modernized Metric System), Standard Practice for

(Application for copies should be addressed to the American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.)

AMERICAN WELDING SOCIETY (AWS)

No number	-	Brazing Manual
No number	-	Soldering Manual
AWS D1.1	-	Structural Welding Code Steel
AWS D1.2	-	Structural Welding Code Aluminum
AWS D1.3	-	Structural Welding Code Sheet Steel

(Application for copies should be addressed to the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.)

COMPRESSED GAS ASSOCIATION (CGA)

CGA C-4	-	Method of Marking Portable Compressed Gas Containers to Identify the Material Contained
CGA C-7	-	Guide to the Preparation of Precautionary Labeling and Marking of Compressed Gas Containers

(Application for copies should be addressed to the Compressed Gas Association, Inc., 1725 Jefferson Davis Highway, Suite 1004, Arlington, VA 22202-4102.)

ELECTRONIC INDUSTRIES ASSOCIATION (EIA)

EIA 310	-	Cabinets, Racks, Panels, and Associated Equipment

(Application for copies should be addressed to the Electronic Industries Association, 2500 Wilson Boulevard, Arlington, VA 22201-3834.)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

ANSI/IEEE 268	-	American National Standard for Metric Practice

(Application for copies should be addressed to IEEE, 345 E. 47th Street, New York, NY 10017 or 445 Hose Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.)

INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS

No number	-	Uniform Building Code

(Application for copies should be addressed to the International Conference of Building Officials, 5360 Workman Mill Road, Whittier, CA 90601-2298.)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ICS 2	-	Industrial Control and Systems Controllers, Contractors, and Overload Relays Rated Not More Than 2000 Volts AC or 750 Volts DC
MG 1	-	Motors and Generators

(Application for copies should be addressed to the National Electrical Manufacturers Association, 1300 N. 17th Street, Suite 1847, Rosslyn, VA 22209.)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 50	-	Standard for Bulk Oxygen Systems at Consumer Sites
NFPA 50B	-	Standard for Liquified Hydrogen Systems at Consumer Sites

NFPA 70	-	National Electrical Code
NFPA 496	-	Standard for Purged and Pressurized Enclosures for Electrical Equipment in Hazardous Locations
NFPA 780	-	Standard for Installation of Lightning Protection Systems

(Application for copies should be addressed to the National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

ARP 1247B	-	General Requirements for Aerospace Ground Support Equipment, Motorized and Nonmotorized
AS 1097	-	Seal Ring

(Application for copies should be addressed to the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.)

SPRING MANUFACTURERS INSTITUTE (SMI)

No number	-	Handbook for Spring Design

(Application for copies should be addressed to the Spring Manufacturers Association, 2001 Midwest Road, Suite 106, Oak Brook, IL 60521.)

2.4 Order of precedence. In the event of conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Acronyms used in this standard. The acronyms used in this standard are:

AA	Aluminum Association
ac	alternating current
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute

ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASQC	American Society for Quality Control
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CFC	chlorofluorocarbon
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CIL	Critical Items List
COTS	commercial off-the-shelf
ECS	environmental control system
EEE	electrical, electronic, and electromechanical
e.g.	for example
EIA	Electronic Industries Association
EMC	Engineering Management Council
EMI	electromagnetic interference
FED	Federal
FMECA	Failure Mode, Effects, and Criticality Analysis
GFE	Government-furnished equipment
GFI	Government-furnished information
GFL	Government-furnished labor
GFP	Government-furnished property
GFS	Government-furnished software
GP	general publication (KSC)
GSE	ground support equipment
HDBK	handbook
ICD	interface control document
i.e.	that is
IEEE	Institute of Electrical and Electronics Engineers
IPC	interconnecting and packaging electronic circuits
JSC	Lyndon B. Johnson Space Center
KHB	KSC handbook
KSC	John F. Kennedy Space Center
LH_2	liquid hydrogen
LHe	liquid helium
LO_2	liquid oxygen
MIL	military
MMH	monomethylhydrazine
MPa	megapascal
MS	military standard
MSFC	George C. Marshall Space Flight Center
MUA	Material Usage Agreement
NAS	National Aerospace Standard
NASA	National Aeronautics and Space Administration
NBS	National Bureau of Standards

NDT	nondestructive test
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NHB	NASA handbook
NIOSH	National Institute for Occupational Safety and Health
NH_3	ammonia
N_2H_4	hydrazine
NMI	NASA management instruction
N_2O_4	nitrogen tetroxide
OMD	operations and maintenance documentation
ORD	operational readiness date
PC	printed circuit
PCB	polychlorobiphenyl
PHE	Propellant Handlers Ensemble
psi	pound per square inch
SAE	Society of Automotive Engineers
SCC	stress corrosion cracking
SMI	Spring Manufacturers Institute
SPEC	specification
STD	standard
TM	technical manual
UBC	Uniform Building Code
°C	degree Celsius
°F	degree Fahrenheit

3.2 Commercial off-the-shelf (COTS). Equipment, including hardware and associated software/procedures, that is commercially available from current industry inventory and is designed to commercial standards.

3.3 Critical weld. A weld whose single failure during any operating condition could result in injury to personnel or damage to property or flight hardware.

3.4 Flight hardware. Hardware intended for launch into space including booster, engines, payload, and manned or unmanned components.

3.5 Ground support equipment. Nonflight systems, equipment, or devices (with a physical or functional interface with flight hardware) necessary to routinely support the operations of transporting, receiving, handling, assembly, inspection, test, checkout, servicing, and launch of space vehicles and payloads at launch, landing, or retrieval sites.

3.6 Safe working load. An assigned load, as shown on the identification tag, that is the maximum load the device or equipment shall operationally handle and maintain.

3.7 Safety critical. Any condition, event, operation, process, equipment, or system with a potential for personnel injury, fatality, or damage to or loss of flight hardware, equipment, or property.

3.8 Safety factor. A ratio of ultimate strength, breaking strength, or yield strength to the maximum material design stress.

4. GENERAL REQUIREMENTS

4.1 General. The general design criteria and practices specified herein shall be the minimum criteria necessary to meet the needs and expectations of internal NASA customers (e.g., safety, reliability, maintainability, quality, supportability, etc.) in a cost-effective manner. In order to meet customer expectations, individual system and equipment design projects may need criteria that are more stringent than those specified herein. In such cases, criteria that exceed the provisions specified herein shall be determined by the responsible design organization in consultation with its customers (e.g., users, operators, etc.).

4.2 Functional designations. The GSE covered by this standard may be classified according to one of the following functional designations (e.g., servicing, checkout and test, auxiliary, etc.). Under each functional designation, GSE can be classified by criticality, whereby the GSE either (1) physically or functionally interfaces with flight hardware/software, (2) is classified as safety critical, and/or (3) generates data used in determining flight worthiness/certification. The GSE or system is assessed as safety critical if loss of the GSE or overall system function or improper performance could result in loss of life, loss of flight hardware, or damage to flight hardware. The GSE defined herein shall be subject to the configuration control requirements specified in the approved program/project configuration management plan.

4.2.1 Servicing. Servicing GSE is required for supplying electrical power or fluids to the flight hardware and/or the associated GSE. Typical functions of servicing GSE are those functions of storage, transfer, flushing, purging, pressurizing, conditioning, vapor disposal, and decontamination of propellants and other fluids required by the flight hardware.

4.2.2 Checkout and test. Checkout and test GSE is required in the test and checkout of flight hardware and/or the associated GSE. Typical functions of checkout and test GSE are the functions of stimuli monitoring and evaluation.

4.2.3 Handling and transportation. Handling and transportation GSE is required for the movement and support of flight hardware and/or the associated GSE. Typical types of equipment used in the handling and transportation category are slings, dollies, trailers, shipping containers, support stands, jacks, hoists, strongbacks, and special handling mechanisms (e.g., Payload Ground Handling Mechanism, Vertical Payload Handling Device, etc.).

4.2.4 Auxiliary. Auxiliary GSE is equipment required to align, access, protect, and calibrate flight hardware. Auxiliary GSE includes, but is not limited to, protective devices, access stands and platforms, and alignment or calibration hardware.

4.2.5 Umbilical. Umbilicals are GSE required to interface directly with flight hardware for transfer of fluids, electrical power, or electronic signals to or from the flight vehicle element.

4.3 Characteristics

4.3.1 Performance characteristics

4.3.1.1 Operability. The GSE shall meet the flight hardware operational requirements and shall be designed to ensure it does not degrade or contaminate associated flight or ground systems, subsystems, or experiments during use, checkout, servicing, or handling. The GSE shall provide for ease of operation, maintenance, servicing, and inspection of hardware and software. Care shall be taken to avoid the use of special tools. Handling, servicing, calibration, and maintenance access provisions shall be designed into the GSE.

4.3.1.2 Interfaces. GSE shall meet the requirements of all interfaces with new or existing flight and facility hardware or software. Future system compatibility shall be in accordance with identified interfaces. GSE shall meet the requirements of the applicable interface control document (ICD).

4.3.1.3 Producibility. GSE design shall ensure the ease of production, manufacture, construction, and inspection. Special care shall be taken to avoid imposing close manufacturing tolerances unless required by design and performance.

4.3.2 Physical characteristics

4.3.2.1 Limited life. Use of items with a life of less than the useful life of the GSE for which the items are intended shall be avoided whenever possible. Items with limited life shall be identified. Identified limited-life items shall be controlled from the date of manufacture through operational use, including storage. Provisions shall be made for replacement or refurbishment of these items after a specified age or operating time/cycle. Status of limited-life cycle items and waivers on limited-life items shall be maintained. Elapsed time or cycle indicators shall be employed to accumulate operational time or cycles if critical. Age control of elastomeric parts shall be in accordance with accepted industry methods and practices.

4.3.2.2 Useful life. GSE shall be designed for a useful life appropriate to its mission. Useful life shall be identified by program or mission requirements. During this period, normal preventive maintenance, repair, modifications, or calibration may be accomplished to maintain specified performance.

4.3.2.3 Protective coating. The protective coating of GSE shall be appropriate to the condition, use, and environment to which the GSE will be exposed during its life cycle. The coating shall minimize corrosion and be reflective of its use. Some recommended coating systems may be found in KSC-STD-C-0001 or MSFC-SPEC-250.

4.3.2.4 Colors. The following colors shall be used for the type of GSE indicated. Colors shall be in accordance with FED-STD-595.

Color	Color Chip Number	GSE Type
Gray	26440 or 26251	Electrical/electronic, hydro/pneumatic consoles, racks, and cabinets
Gray	16187 or 16473	Structural steel
Red	11105 or 21105	Remove before flight, safety, and protective equipment
White	17875 or 27875	White room or clean room equipment
Black	37038	Panel lettering
Yellow or White	13538 17875 or 27875	Handling and transportation equipment

4.3.2.5 Metric system. New GSE that supports flight programs or projects that are designed using the metric system of measurement shall also use the metric system for design in accordance with NMI 8010.2. Standard practice for the use of the metric system shall be in accordance with ANSI/IEEE 268 or ASTM E380.

4.3.2.6 Redundancy. Redundant systems, subsystems, or components shall be physically separated or otherwise protected to ensure failure of one will not prevent the other from performing the function.

4.3.3 Reliability. GSE shall be designed to minimize the probability of system failure and reduce the severity of the failure effect of the system. As a minimum, systems shall be designed to be fail-safe (except for primary structure and pressure vessels in the rupture mode). The Failure Mode, Effects, and Criticality Analysis (FMECA)/Critical Items List (CIL) and sneak circuit analysis requirements, including managerial approval of critical items, shall be in accordance with the program management plan.

4.3.4 Maintainability. GSE shall be designed to minimize the complexity and frequency of maintenance, the maintenance resources required to keep the system operational, and maintenance downtime. High-failure-rate items should be identified for accessibility concerns. Fault detection and isolation should be considered based on criticality and cost of failures. Additional maintainability requirements shall be in accordance with the program management plan.

4.3.5 Environmental conditions. GSE shall be designed to withstand natural and induced environments to which it will be subjected during its life cycle. GSE shall also be designed in accordance with the applicable environmental regulations.

4.3.5.1 Natural environment. GSE used or stored in an exterior environment shall be designed to function properly at its respective geographical location after exposure to the natural environment as specified in TM-4511 and as tailored to reflect program-defined risk and exposure times.

4.3.5.2 Launch-induced environment. GSE designed to function during or after exposure to the launch-induced environment shall be designed to withstand the environment defined in program-induced environmental requirements documents. GSE designed not to function after exposure to the launch-induced environment shall not cause damage to the flight hardware, facilities, or other GSE.

4.3.5.3 Controlled interior environment. GSE designed to function within a controlled interior environment shall be designed to the following temperature and humidity requirements:

a. Temperature: +15.6 degrees Celsius (°C) [60 degrees Fahrenheit (°F)] to +26.7 °C (80 °F) with extremes of an uncontrolled temperature of +11.1 °C (52 °F) to +40.6 °C (105 °F) for a maximum of 1 hour
b. Humidity: nominal 60 percent, with a range of 45 to 70 percent at 21.1 ±5 °C (70 ±10 °F)

4.3.5.4 Controlled clean environment. GSE used in a controlled clean environment shall be designed to be operated and maintained at a cleanliness level compatible with the intended use in accordance with NSTS-SN-C-0005.

4.3.5.5 Uncontrolled interior environment. GSE used in an uncontrolled interior environment shall be designed to meet the most severe exterior environmental conditions for temperature and humidity anticipated at the respective geographical locations.

4.3.5.6 Fire/explosion hazard environment. GSE operated in locations where fire or explosion hazards may exist, as defined by NFPA 70, Article 500, shall be listed by a nationally recognized testing agency for use in that location in accordance with NFPA 70 or shall be purged and pressurized in accordance with the requirements of NFPA 496.

4.3.5.7 Environmental test methods. Environmental methods and conditions required for GSE testing and qualification shall be in accordance with MIL-STD-810, as applicable.

4.3.5.8 Seismic environment. If GSE may be subjected to a seismic environment, GSE shall be designed to resist the effects of a seismic event using the criteria and guidelines contained in TM 5-809-10/NAVFAC P-355/AFM 88-3, Chapter 13, or the Uniform Building Code (UBC).

4.3.6 Transportability. GSE shall be designed to be suitable for normal transportation methods. GSE to be transported by personnel shall be provided with such handling provisions (e.g., handles, hand holds, etc.) necessary to meet operational transportability requirements. GSE that exceeds personnel lifting limits shall be provided with material handling provisions (e.g., sling, lift points, castors, skid, etc.) necessary to meet the operational requirements for installation/removal, maintenance, and use.

4.4 Documentation

4.4.1 Drawings and specifications. Drawings and specifications required for the fabrication, construction, installation, modification, test, operation, maintenance, or utilization of GSE shall be prepared in accordance with drawing practices equal to or more stringent than the American Society of Mechanical Engineers (ASME) engineering drawing and related documentation practices.

4.4.2 Technical documentation. Technical documentation (e.g., manuals, reports, etc.) shall be prepared in accordance with accepted industrial practices, as applicable.

4.4.3 Operations and maintenance documentation (OMD). Operations and maintenance documentation (e.g., schematics, diagrams, operation and maintenance manuals, lists, etc.) shall be developed to the extent necessary to permit operations and maintenance personnel to fully utilize, operate, troubleshoot, and otherwise maintain the GSE within their charge.

4.5 Logistics. GSE design shall accommodate logistic conditions such as spares provisioning considerations and supply system requirements. System and equipment design shall identify and acquire sufficient spare parts, components, materials, and items to support construction, fabrication, installation, activation, tests, and verification activities that occur prior to the operational readiness date (ORD) of the equipment or system. Logistic support during operations shall be provided by the operations and maintenance organizations.

4.6 Personnel and training. GSE design shall minimize the personnel and training requirements for the operation and maintenance of hardware and software. GSE design shall keep the number and skill levels of personnel to a minimum. OMD shall be provided as required to meet personnel training requirements. Specialized training may be required in those applications where GSE is complex enough to warrant. All GSE will be designed assuming operations and maintenance will be performed by appropriately trained and skilled personnel, unless otherwise directed.

When a design must accommodate unskilled and untrained users, the GSE shall be designed for simplicity of use, with redundancy and controls that are self-explanatory. The design shall provide for appropriate safety and warning devices to alert personnel of impending or existing hazards and shall ensure failure will not adversely affect personnel safety or the safety of the system or equipment. The design shall limit the number of controls and the data provided to the absolute minimum possible so only those functions needed by an unskilled and untrained operator are available. The design shall provide ease of operation so unskilled and untrained operators do not require training for normal

or emergency conditions. Design features shall ensure ease of operation, safety, and economy. The resultant design shall optimize compatibility between equipment and human performance without requiring personnel training.

4.7 Qualification. Critical systems and other components that have significant failure impact shall be qualified in accordance with the provisions of the approved program/project verification plan.

4.8 Quality assurance

4.8.1 General. GSE design shall incorporate program/project technical quality requirements in accordance with ANSI/ASQC Q9001. The design shall also include special quality-related requirements, such as special processes, special testing, and any other necessary special requirements that produce a quality product. Quality requirements will be defined in program/project quality and technical requirements documents, specifications, contractual requirements, and other specified documentation.

4.8.2 Responsibility for verification. The concept of quality assurance places primary responsibility for quality of delivered products, materials, or services on the supplier or contractor. The contractor is also responsible for the verification/quality of subcontractor products. However, where assembly of the GSE is at a Government facility, responsibility for verification may be split between the Government and the contractor. Accordingly, the supplier's responsibility for inspection shall be clearly stated in the contract documentation; and the Government's role, either as a partner or monitor, shall be specified. A typical statement of responsibility is:

> Responsibility for verification. Unless otherwise specified in the contract or order, the supplier is responsible for the performance of all verification requirements specified herein. Except as otherwise specified, the supplier may use its own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the verifications set forth in the specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.8.3 Testing. Testing shall be specified by the engineering documentation and will normally be limited to end-item acceptance testing to verify compliance with the applicable specifications and the ability of the end item to perform its functions.

4.8.3.1 Load test. A load test shall be performed on GSE whenever there is reason to question its safety for the intended use. The minimum test load shall be 125 percent of the design or working load. Lifting devices and equipment shall be load tested in accordance with NSS GO-1740.9. GSE that has been successfully load tested shall be identified in accordance with this standard.

4.8.3.2 Nondestructive test (NDT). NDT shall be performed in accordance with MIL-I-6870.

4.8.3.3 Test reports. Test reports shall be prepared in accordance with accepted industry practice.

4.8.3.4 Instrumentation calibration. Calibration of measuring instruments shall be established and maintained in accordance with ANSI/ASQC Q9001.

4.8.4 Quality conformance verification. A verification program shall be specified in the program/project verification plan and in the contract documentation. Examinations and tests are recommended to verify all requirements of sections 4 and 5 of this standard have been achieved. This quality conformance verification program may include:

a. Tests and analyses of the performance and reliability requirements

b. Measurement or comparison of specified physical characteristics

c. Verification, with specific criteria, of workmanship

d. Test and inspection methods for ensuring compliance, including environmental conditions for performance

4.9 Packaging

4.9.1 Preservation and packaging. GSE shall be preserved and packaged in such a manner so as to protect and preserve the item prior to installation or use.

4.9.2 Shipping containers. Shipping containers shall be compatible with onsite transportation, handling, and storage methods. For convenient handling and stacking, containers having a gross weight of more than 65 kilograms (150 pounds) shall be provided with integral skids or pallets for shipment. Attach points shall be provided where applicable for crane hoists and tiedowns. Shipping containers that are classified as GSE shall be subject to the design and load testing criteria specified in this standard.

4.9.3 Weight and size. The weight and cubic displacement of packaging and packing shall be held to a minimum consistent with the requirement of the item and the method of transportation. GSE shall be designed so the configuration (i.e., item) may be disassembled as required and packaged for shipment.

4.9.4 Parts protection. There shall be an efficient, reliable, and economical system for the protection of all parts during manufacturing processes and inplant handling and storage. There shall be standardization of parts protection procedures, methods, materials, and devices, such as carts, boxes, containers, or transportation vehicles necessary to prevent damage to parts.

4.9.5 Precision clean parts. Precision clean parts shall be packaged in such a manner so as to preserve the cleaning level of the part until used.

4.9.6 Marking. Containers shall be marked in such a manner so as to easily identify the contents of the container without opening it.

4.9.7 Environmental recording instruments. Shipment of GSE that is sensitive to the environment shall include instruments that record the environment with respect to time. Proof of adequate packaging shall be demonstrated if the use of a recording instrument is required but is not feasible in a single-item shipment of a small item.

4.9.8 Transportation and storage. The packaging shall protect the GSE during transportation and storage.

5. DETAILED REQUIREMENTS

5.1 Structural design

5.1.1 Structural steel and other structures. The design of structural steel, aluminum, concrete, and other GSE structures (e.g., access platforms, support stands, etc.) shall be in accordance with M016, M015L, SAS 30, SAS 33, AISI SG 673 (Part 1), or ACI 318 and the requirements specified in this standard.

5.1.2 Safety factor. If there is no applicable standard when using the allowable stress design method, a minimum safety factor of 2 against yield or permanent deformation and 3 against ultimate failure or collapse shall be used. The safety factor shall not be used to justify exceeding the safe working load.

5.1.3 Scaffolding. Access scaffolding shall be designed in accordance with ANSI A10.8 and 29 CFR 1910.28.

5.1.4 Critical weld. Critical welds shall be avoided wherever possible. Critical welds shall be identified by the responsible design organization on the design drawings by placing a flag note in the tail of the critical weld symbol. The required appropriate nondestructive testing for critical welds shall also be identified by the responsible design organization in the general notes on the design drawings.

5.2 Mechanical design

5.2.1 Pneumatics. The design of pneumatic (i.e., gaseous nitrogen, helium, oxygen, hydrogen, breathing air, and special oxygen/nitrogen mixtures) servicing GSE shall be in accordance with KSC-STD-Z-0005. Compressed air systems with an operating gage pressure of 1.7 megapascals (MPa) [250 pounds per square inch (psi)] or less and vacuum systems shall be designed in accordance with accepted industry standards, as applicable. Breathing air systems shall also conform to 29 CFR 1910.

5.2.2 Cryogenics. The design of cryogenic [i.e., liquid hydrogen (LH_2) and liquid oxygen (LO_2)] servicing GSE shall be in accordance with NFPA 50 or NFPA 50B, as applicable. The design of liquid helium (LHe) or other cryogenic servicing GSE shall be in accordance with accepted industry standards, as applicable.

5.2.3 Hypergols. The design of hypergolic [monomethylhydrazine (MMH), nitrogen tetroxide (N_2O_4), hydrazine (N_2H_4), and Aerozine-50 (A-50)] fuel or oxidizer servicing GSE shall be in accordance with the provisions of KSC-STD-Z-0006.

5.2.4 Hydrocarbons. The design of hydrocarbon fuel [i.e., JP-4, JP-5, RP-1, and American Society for Testing and Materials (ASTM) jet fuels A and B] servicing and storage GSE shall be in accordance with ASME B31.3.

5.2.5 Hydraulics. The design of hydraulic servicing GSE shall be in accordance with ASME B31.3 and with KSC-STD-Z-0005 as a guide for principles common to both hydraulics and pneumatics.

5.2.6 Environmental control system (ECS) and coolant servicing systems. The design of ECS and coolant servicing GSE used to condition and control the environment within selected space vehicle, spacecraft, or experiment compartments shall be in accordance with American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) handbooks. Environments in which personnel may be exposed shall be maintained to conditions specified in MIL-STD-1472.

5.2.7 Life support. The design of life support GSE used or worn by personnel involved in toxic material operations, emergency rescue operations, and all activities where the possibility of exposure to hazardous atmosphere exists shall be in accordance with KSC-STD-Z-0008, National Institute for Occupational Safety and Health (NIOSH), and National Fire Protection Association (NFPA) requirements.

5.2.8 Lifting devices. The design of lifting devices (e.g., cranes, crane girders, hoists, lifting slings, etc.) shall be in accordance with NSS/GO-1740.9. When lifting flight hardware, a liftability analysis shall be performed to certify the stability of the lift prior to completion of the final design.

5.2.9 Springs. Spring design shall be in accordance with the Handbook for Spring Design, from the Spring Manufacturers Institute.

5.2.10 Umbilical design. The design of umbilicals shall use GP-986 as a guide.

5.2.11 Torque limits. For threaded fasteners 32 millimeters (1-1/4 inches) and less in diameter, torquing criteria shall be as specified in MSFC-STD-486, as a minimum. For threaded fasteners of diameters greater than 32 millimeters, torquing requirements shall be determined by appropriate design analysis methods. Torquing criteria for structural bolts, such as ASTM A325 and A490, shall be in accordance with either M015L or M016 as appropriate.

5.2.12 Tethers. Equipment used in areas where the dropping of hardware could result in injury to personnel or damage to flight hardware shall be tethered.

5.2.13 Jacks. The design of jacks shall be in accordance with ASME B30.1.

5.2.14 Transportation equipment. Transporters and other motorized GSE used for transportation of flight elements shall be designed to system specifications compiled from appropriate sections of ARP 1247B, MIL-M-8090, and other industry and military specifications applicable to the characteristics of the desired end item. GSE requiring mobility shall be designed in accordance with applicable sections of MIL-M-8090. Transportation equipment shall ensure loads imparted to flight hardware are equal to or less than 80 percent of the design flight loads.

5.2.15 Pressure vessels. All pressure vessels for use in GSE shall be designed, constructed, tested, and certified in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division I or II. All ASME code stamped vessels shall be registered with the National Board of Boiler and Pressure Vessel Inspectors. Pressure vessels utilized for transportation containing a product shall meet the Department of Transportation requirements in 49 CFR 171 through 181.

5.3 Electrical/electronic design

5.3.1 Electrical control and monitor equipment. The design of electrical control and monitor GSE shall be in accordance with MIL-HDBK-454.

5.3.2 Pneumatic and hydraulic mechanical components. The electrical design for pneumatic and hydraulic mechanical components shall be in accordance with KSC-STD-E-0004.

5.3.3 Internal wiring. The design of internal wiring used for electrical interconnection of components or parts within electronic GSE shall be in accordance with MIL-HDBK-454. Wire terminations shall be in accordance with MIL-HDBK-454.

5.3.4 Pyrotechnic systems. The design of pyrotechnic GSE shall be in accordance with MIL-STD-1576.

5.3.5 Electrical power. The design of electrical power for GSE shall be in accordance with NFPA 70.

5.3.6 Bonding and grounding. Bonding and grounding shall be provided in accordance with NFPA 70.

5.3.7 Hazardproofing. Hazardproofing of electrically energized equipment shall be in accordance with NFPA 496.

5.3.8 Lightning protection. Lightning protection for GSE located at the launch pads, hazardous processing facilities, and other hazardous areas shall be designed in accordance with NFPA 780.

5.3.9 Software. Software incorporated in the design of GSE shall meet the requirements of the appropriate Institute of Electrical and Electronic Engineers (IEEE) specification or standard.

5.3.10 Firmware. Firmware incorporated in the design of GSE shall meet the requirements of the appropriate IEEE specifications.

5.4 Materials, parts, and processes

5.4.1 Materials. Recovered or recycled materials shall be used instead of virgin materials except in those cases where virgin materials are deemed necessary to ensure adequate performance. For establishing properties, MIL-HDBK-5 shall be used for metal, MIL-HDBK-149 for rubber, and MIL-HDBK-700 for plastics. Applications for materials shall be limited to those materials that are adequately described by controlling specifications or standards of a cognizant authority. Any additional qualifying tests and inspec-tions shall be indicated in the engineering documentation. Control documents may be created for proposed materials that lack such documentation. Noncompliance with the material requirements specified herein may be approved by preparation and approval of a Material Usage Agreement (MUA) in accordance with NASA installation procedures.

5.4.1.1 Hydrogen embrittlement. Materials subject to hydrogen embrittlement shall not be used in applications where the material could be exposed to hydrogen. These materials include, but are not limited to, titanium, maraging steels, 400-series stainless steels, steel in accordance with MIL-S-16216 or ASTM A514 and ASTM A517, steels listed in section 2.3 of MIL-HDBK-5, and precipitation-hardening stainless steels. Low-strength carbon and stainless steels, such as ASTM A-36 and AISI 304, AISI 304L, AISI 316, AISI CF8, and AISI CF8M stainless steels, are preferred construction materials. When hydrogen-generating processes such as inorganic finishing or plating are utilized, the appropriate embrittlement relief procedure specified in MSFC-SPEC-250 shall be used.

5.4.1.2 Stress corrosion. Materials shall be selected from alloys that are highly resistant to stress corrosion cracking (SCC) as specified in MSFC-SPEC-522.

5.4.1.3 Dissimilar metals. Dissimilar metals in accordance with MIL-STD-889 shall not be used in direct contact with each other. Separation by use of barrier tape, protective coatings, or other methods of isolation shall be used in accordance with MIL-STD-889.

5.4.1.4 Toxic materials or formulations. Toxic materials or formulations shall not be specified in GSE design. Toxic products and formulations shall not be generated by GSE. Typical examples of such toxic materials are mercury in liquid or vapor form, polychlorobiphenyls (PCB's), lead-based paints, chlorofluorocarbons (CFC's), and asbestos. Toxic fluids such as N_2H_4, N_2O_4, MMH, and ammonia (NH_3) may only be used when

specifically required by a flight vehicle system requirement. The use of such toxic fluids shall comply with the applicable safety and environmental regulations. A material's hazardous analysis shall be performed to determine if the GSE design involves any materials or byproducts that may be considered hazardous.

5.4.1.5 Flammability, odor, and offgassing. Materials used in GSE designed for use in direct contact with the flight vehicle element or in close proximity shall be qualified for flammability, odor, and offgassing in accordance with NHB 8060.1, as required.

5.4.1.5.1 Oxygen service. Only materials that are compatible with oxygen shall be present for use in liquid or gaseous oxygen and liquid or gaseous air systems. Approved oxygen-compatible materials shall be qualified in accordance with NHB 8060.1

5.4.1.5.2 Type J fluid service. Only materials that are compatible with type J fluids (e.g., hydrogen, hypergols, etc.) shall be used in these systems. Approved type J compatible materials shall be qualified in accordance with NHB 8060.1.

5.4.1.6 Heat and blast protection. Coating materials used for heat and blast protection of GSE shall be compatible with the flight vehicle propellents, shall not create debris, and shall protect the hardware to which it is applied with a minimum of repair after launch.

5.4.1.7 Potting and molding compound. Potting and molding compound for electrical connectors shall be in accordance with KSC-SPEC-E-0029, MSFC-SPEC-515, or MSFC-SPEC-222 or MSFC-SPEC-379.

5.4.1.8 Fungus resistance. Materials shall be resistant to the degrading effects of moisture and reversion. Materials shall be selected that are nonnutrient to fungi as defined by MIL-STD-810, Method 508, or MIL-HDBK-454. When these materials cannot be avoided, the material shall be treated to resist fungus.

5.4.1.9 Liquid locking compounds. Single component liquid locking compounds that are anaerobic (remain liquid when exposed to oxygen) shall not be used without prior project/program approval.

5.4.2 Parts

5.4.2.1 Use of commercial items. Commercial off-the-shelf (COTS) equipment, parts, items, software, or components shall be used to the maximum extent possible when (1) they satisfy the hardware function, (2) they will not degrade the safety or reliability of the flight or ground system, and (3) they provide a cost savings that will exceed possible cost increases due to unique maintenance or logistics requirements, modifications, or an increase in the complexity of the interfacing equipment. In all cases, exact materials of construction and applicable specifications shall be determined for evaluation of material compatibility with requirements. Any additional qualifying tests and inspections shall be

indicated in the engineering documentation. Control documents may be created for proposed parts that lack such documentation.

5.4.2.2 Electrical, electronic, and electromechanical (EEE) parts. EEE parts shall be selected from MIL-STD-975. Only EEE parts commensurate with the criticality of the application and the life cycle of the GSE shall be used. Determination of the EEE grade shall be based on the specific circuit function and its associated criticality. MIL-STD-701 shall be used when MIL-STD-975 does not list the required semiconductor device.

5.4.2.3 Tubing and fittings. Tube fittings used in high-pressure fluid systems shall use a seal ring in accordance with AS 1097 and shall comply with SAE fitting specifications. Tubing shall be in accordance with ASTM A269.

5.4.2.4 Fluid system components. Fluid system components used in the design of liquid or gas systems shall be limited to those items that are adequately described by controlling specifications or standards of a cognizant authority. Control documents may be created for proposed fluid components that lack such documentation. Fluid components shall be selected for design utilization based upon the severity of the application. For applications where safety of personnel, damage to flight hardware, or loss of mission is a direct concern, fluid components shall be selected from items of the highest practical quality.

5.4.2.5 Electrical power receptacles and plugs. Electrical power receptacles and plugs for GSE shall be in accordance with NFPA 70.

5.4.2.6 Electrical power cable. Sixty-hertz alternating current (ac) power cable shall be in accordance with NFPA 70.

5.4.2.7 Electrical cable. Flexible multiconductor jacketed electrical cable shall be in accordance with KSC-SPEC-E-0031.

5.4.2.8 Fiber-optic cable. Fiber-optic cable shall be in accordance with Electronic Industries Association (EIA) specifications and standards.

5.4.2.9 Electrical hookup wire. Electrical hookup wire shall be in accordance with MIL-W-5086, MIL-W-16878, or MIL-W-22759.

5.4.2.10 Connectors. Electrical multiconductor connectors for electrical control and monitor GSE shall be selected from the following basic families of connectors: MIL-C-5015, MIL-C-22992, MIL-C-26482, and MIL-C-38999. Connectors shown in MIL-STD-975 are also recommended.

5.4.2.10.1 Coaxial (RF) connectors. Coaxial (RF) connectors shall be selected from MIL-C-39012.

5.4.2.10.2 Protective covers or caps. Protective covers or caps shall be specified for all electrical connector plugs and receptacles when they are not connected. Protective covers or caps shall meet the following requirements:

a. Be moistureproof

b. Protect sealings, surfaces, threads, and pins against damage

c. Be resistant to abrasion, chipping, or flaking

d. Comply with cleanliness requirements for plugs and receptacles on which they are used

e. Be made of material that is compatible with the connector materials and is nonstatic producing

f. Be connected to the cable with suitable lanyard, chain, or hinge

5.4.2.11 Sensors and transducers. Sensors and transducers used in the design of electrical control and monitor systems shall be limited to those items that are adequately described by controlling specifications or standards of a cognizant field center authority. Control documents may be created for proposed sensors and transducers that lack such documentation. Sensors and transducers shall be selected for design utilization based upon the severity of the application. For applications where safety of personnel, damage to flight hardware, or loss of mission is a direct concern, sensors and transducers shall be selected from items of the highest practical quality.

5.4.2.12 Exterior electrical enclosures. Electrical enclosures used in exterior applications shall be in accordance with NFPA 496.

5.4.2.13 Racks, panels, and modular enclosures. Electronic racks, panels, and modular enclosures used in interior applications shall be in accordance with EIA 310.

5.4.2.14 Printed circuit (PC) boards. Specifications and standards prepared and published by the Institute of Interconnecting and Packaging Electronic Circuits (IPC) shall be used in applications where such use will ensure acceptable items.

5.4.2.15 Motors. Motors used in GSE shall be in accordance with National Electrical Manufacturers Association (NEMA) standard MG 1. Starters and controllers shall be in accordance with NEMA standards for industrial control specified in ICS 2 and NFPA 70. Motors rated at 28 volts direct current shall conform to MIL-M-8609.

5.4.2.16 Threaded fasteners. Threaded fasteners shall be limited to those items that are adequately described by controlling specifications or standards of a cognizant authority (e.g., ASTM, NAS, MS, etc.). Control documents may be created for proposed fasteners that lack such documentation. Fasteners shall be selected for design utilization based upon the severity of the application. For applications where safety of personnel,

damage to flight hardware, or loss of mission is a direct concern, fasteners shall be selected from items of the highest practical quality. These critical fasteners shall have lot traceability from the manufacturer to the warehouse storage or shall have acceptance testing (chemical and physical properties, where applicable) of fasteners by lot or be proof-loaded prior to use. Other applications shall give primary consideration to reduced cost and schedule requirements.

5.4.3 Processes

5.4.3.1 Welding. Welding shall be in accordance with the following specifications or the appropriate NASA specification for welding of GSE:

Specification	Subject
AWS D1.1	Structural steel
AWS D1.2	Structural aluminum
AWS D1.3	Sheet steel
Vessel Codes, Section IX	ASME Boiler and Pressure Pressure vessel welding and brazing

5.4.3.2 Brazing. Brazing of steel, copper, aluminum, nickel, and magnesium alloys shall be in accordance with the AWS Brazing Manual. Brazing shall meet the requirements of MIL-B-7883.

5.4.3.3 Soldering. Soldering shall be in accordance with the AWS Soldering Manual.

5.4.3.4 Tube assembly. Fabrication and installation of flared tube assemblies shall be in accordance with KSC-SPEC-Z-0008.

5.4.3.5 Fitting lubrication. Lubrication of flared tube fittings shall be in accordance with KSC-SPEC-Z-0009.

5.4.3.6 Fluid system cleaning. Cleaning of piping, tubing, fittings, and other fluid system components shall be in accordance with KSC-C-123 or MSFC-SPEC-164. The cleanliness level and test method shall be specified based upon the application.

5.4.3.7 Riveting. Riveting on GSE shall be in accordance with MSFC-STD-156.

5.4.3.8 Crimping. Crimping shall be in accordance with KSC-E-165.

5.4.3.9 Potting and molding. Potting and molding of electrical connectors shall be in accordance with KSC-E-165, MSFC-PROC-380, or MSFC-PROC-186.

5.4.3.10 Electrical cable fabrication. Electrical cable fabrication for control and monitor GSE shall be in accordance with KSC-E-165.

5.4.3.11 Corrosion control. Corrosion control shall be provided for GSE to minimize concentration cell, galvanic, intergranular, pitting, stress, and crevice corrosion when subjected to the natural and induced environment anticipated during the life cycle. Appropriate methods for corrosion removal, cleaning, treatment, and coating shall be developed to minimize the effects of corrosion.

5.4.3.12 Metal treatment and plating. Metal treatment (including passivation of stainless steel) and plating shall be in accordance with MIL-STD-171. Cadmium plating shall not be used.

5.4.3.13 Heat treating. All heat treating of steel shall be performed in accordance with MIL-H-6875. All heat treating of aluminum shall be performed in accordance with MIL-H-6088. Heat treating of titanium and titanium alloy parts shall meet the requirements of MIL-H-81200.

5.5 Electromagnetic interference (EMI). Electrical and electronic systems shall be designed to minimize the generation of and susceptibility to EMI in order to eliminate any possible deterioration of the performance of the system and surrounding systems. Where applicable, GSE may require compliance with the requirements of MIL-STD-461. EMI characteristics shall be measured in accordance with MIL-STD-462.

5.6 Identification markings and labels

5.6.1 Systems and equipment. GSE shall be identified and marked to indicate the part number, name, and serial number or reference designation, as applicable.

5.6.2 Load test. GSE that has been load tested satisfactorily shall be identified and marked to show the load test date, safe working load, test load, retest date, and quality acceptance.

5.6.3 Piping systems. Ground piping systems shall be identified and color coded to indicate the type of fluid contained within, the direction of the flow, and the maximum operating pressure. See ASME A13.1 for a suggested scheme.

5.6.4 Compressed gas cylinders. Compressed gas cylinders shall be identified and color coded in accordance with CGA C-4 and CGA C-7.

5.6.5 Load capacity. GSE used for hoisting, transportation, handling, and personnel access shall be conspicuously marked to indicate the maximum safe working load.

5.6.6 Test weights. Prior to the first usage, all test weights shall be weighed and marked in accordance with the requirements specified herein:

a. Manufactured or fabricated test weights provided by a vendor shall be weighed and marked by the vendor prior to acceptance by the Government.

b. Test weight marking shall be sufficiently large so the load value is visible to the load test operator at normal working distances up to 6 meters (20 feet). Letters 150 millimeters (6 inches) high are suggested.

c. Square and rectangular test weights shall have the weight value painted in a contrasting color on two opposite sides. Markings shall be placed so they are visible when weights are stacked.

d. Cylindrical test weights shall have the weight value painted in a contrasting color at two points that are approximately diametrically opposite.

e. Large class F field standard weights up to 4500 kilograms (10,000 pounds) used as test weights shall conform to the marking requirements of NBS Handbook 105-1, Section 8.

f. After initial marking, test weights shall not be reweighed and remarked unless the test weights are modified or the physical marking is lost. If the test weights are modified in such a way as to significantly change the weight, they shall not be used until they are reweighed and remarked.

g. The weighing and marking of test weights shall be specified on the engineering drawings.

h. In those special cases where there is no practical method of weighing test weights, the calculated weight shall be used, and the words "calculated weight" shall be noted for weight identification.

i. Test weight fixtures or weight cages used for single or multiple weight tests shall be marked in accordance with this paragraph. The words "fixture weight" shall be noted for weight identification.

5.6.7 Electrical cable assemblies. Electrical cable assemblies shall be identified at each end of the cable and labeled to show the assembly part number, cable reference designation number, and cable end marking.

5.6.8 Serial numbers. Serial numbers shall be required on those items, components, or assemblies that contain limited-life parts (e.g., valves, regulators, etc.) or that require periodic inspection, checkout, repair, maintenance, servicing, or calibration (e.g., pressure transducers, gages, switches, torque wrench, etc.).

5.7 Workmanship. GSE shall be fabricated and finished so appearance, fit, and adherence to specified dimensions and tolerances are observed and in a manner that

ensures reliable operations in accordance with the requirements specified herein. Particular attention shall be given to the neatness and thoroughness of construction and to the freedom of parts from burrs and sharp edges that might damage associated equipment or cause injury to personnel.

5.8 Interchangeability. Hardware assemblies, components, and parts that are physically and functionally interchangeable shall be assigned the same part number.

5.9 Safety. Safety requirements shall be in accordance with 29 CFR 1910 and EWR 127-1, and with KHB 1700.7 for Shuttle payloads.

5.10 Human performance. Design criteria for human performance shall be in accordance with the following requirements:

5.10.1 Human engineering. MIL-STD-1472 shall be used to establish human engineering criteria for GSE design.

5.10.2 Operating characteristics. Noise, light, smoke, fumes, heat, and vibration created by equipment shall not exceed the limits defined in human engineering criteria and 29 CFR 1910.

5.10.3 Personnel lifting limits. Human engineering criteria shall be used to determine the maximum weight that one or two people can lift, carry, or handle. Special consideration shall be given to equipment handling adjacent to or inside flight vehicle elements.

5.10.4 Propellant handlers ensemble (PHE) operators. GSE shall be designed to minimize the requirement for operations and maintenance personnel to wear protective clothing such as a PHE [previously called Self-Contained Atmospheric Protective Ensemble (SCAPE)] during normal operations and maintenance. Valves, gages, levers, bolts, nuts, and any other item required to be moved, turned, manipulated, or monitored by personnel in a PHE shall be sized to facilitate operation by PHE-suited operators. Such items shall be located to optimize access to the item while the PHE-suited operator is in a standing position. Sufficient clearance shall be provided to preclude brushing against other surfaces. GSE shall be designed to avoid requirements for PHE-suited operators to reach into tight areas, stoop to avoid low overhead obstructions, mount supplementary ladders or stairs, touch rough surfaces, or sit, kneel, or lie on the floors or decks. Suitable provisions to prevent damaging the PHE and to prevent PHE personnel fatigue and discomfort shall be included in the design. Use of expanded surfaces shall be prohibited.

5.11 Security. Security requirements for GSE shall be in accordance with NHB 1620.3.

5.12 Government-furnished property. Government-furnished property (GFP), in the form of equipment (GFE), software (GFS), information (GFI), or labor (GFL), shall not

be incorporated into GSE design except where there is savings to the Government in cost, schedule, or performance.

6. NOTES

6.1 Intended use. This standard is intended to be used in the establishment of uniform engineering practices and methods and to ensure the inclusion of essential requirements in the design of GSE used to support the operations of receiving, transportation, handling, assembly, inspection, test, checkout, service, and launch of space vehicles and payloads at NASA's launch, landing, or retrieval locations.

Custodian:

NASA-John F. Kennedy Space Center

Preparing Activity:

John F. Kennedy Space Center
Engineering Development Directorate